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Kinematics and kinetics of lower-extremity joints in parachuting landing with backpack and knee brace

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Highlights

- Injuries on hip, knee and ankle were caused in parachuting landing with backpack.
- Without backpack, knee brace could protect hip, knee and ankle.
- With backpack, knee brace could only protect knee.

Abstract

Injuries on lower-extremity joints were caused by high impact force in parachuting landing. Knee brace was used to protect knee by restraining motion of knee. Backpack was necessary in parachuting landing and would increase lower-extremity joints injuries. This study aimed to analyze kinematics and kinetics of hip, knee and ankle for investigating multi-joint protection of knee brace for those joints in parachuting landing with backpack. Seven participants landed from

120 cm height. Kinematics and kinetics of hip, knee and ankle were analyzed. It was found that without backpack knee brace decreased angular displacements of hip (12.0%), knee (10.3%) and ankle (18.6%) on sagittal plane and angular velocities of hip (11.9%), knee (6.6%) and ankle (20.9%) on sagittal plane. With backpack, knee brace decreased angular displacement (5.5%) and angular velocity of knee (6.2%) on sagittal plane, but did not significantly influence those of hip and ankle on sagittal plane. Ground reaction force, joint moments and joint energy absorptions were not significantly influenced with knee brace. In conclusion, in parachuting landing without backpack, knee brace could provide multi-joint protection for hip, knee and ankle. In parachuting landing with backpack, knee brace could still protect knee, but could not protect hip and ankle.

Introduction

Landings were common in military and civil activities. Injuries of the lower-extremity joints (i.e. hip, knee and ankle) would be resulted from high impact force in landings [1], [2], [3]. Parachuting landing was a typical kind of landings characterized by high impact force on lower-extremity. More than 59% of injuries were on the lower-extremity joints [4]. Studying parachuting landing was meaningful for the lower-extremity joints injuries evaluation and prevention under the high impact force.

The lower-extremity joints performed motion in parachuting landing to absorb the impact energy and decrease the impact force. Excessive motion on sagittal plane of the lower-extremity joints would decrease joints stabilization to induce injuries [5]. The excessive motion of lower-extremity joints on coronal plane would also cause injuries in parachuting landing [6]. Injuries of the lower-extremity joints would be decreased by restraining the lower-extremity joints motion [5].

Knee brace could restrain the motion of knee, and was commonly used for protecting knee from injuries in landings [[7], [8], [9], [10]–11]. Kinematic and kinetic parameters, including angular displacement, angular velocity, joints moment and joint energy absorption of lower-extremity joints and ground reaction force, were related to those joints motion, injuries prevention and protection effects evaluation of the knee brace [7,12,13]. The angular displacement of knee on sagittal and coronal planes would be decreased by the elastic knee brace and the semi-rigid knee brace in the parachuting landing [13]. The angular displacement of knee on coronal plane would be decreased by the Reaction Web Knee Brace in the drop landing [1]. The angular displacement of knee on coronal plane was decreased by the silicon web knee brace in the drop landing [14]. The joint moments of knee and ankle were not significantly influenced with the prophylactic knee brace in the double-leg drop landing [7].

In parachuting landing, injuries were high on hip, knee and ankle (5%, 18% and 36% on hip, knee and ankle respectively) [4]. To minimize injuries in parachuting landing, injuries of hip, knee and ankle should be decreased. However, only knee brace or ankle brace was solely worn for protecting knee or ankle respectively in previous studies [1,5,13,15,16]. Therefore, the multi-joint protection for hip,

knee and ankle by a single brace, i.e. only knee brace or ankle brace, were necessary. However, this multi-joint protection had hardly been analyzed. In this study, the kinematical parameters of knee, ankle and hip were analyzed to explore if knee brace could provide the multi-joint protection effects in parachuting landing.

Backpack, including necessities for normal missions and livings, was commonly carried in parachuting landing [17] and other military training landings [12,18]. Injuries would be increased by approximate 60% in parachuting landing with backpack because the impact force was increased [17,19]. With the 15 kg backpack, the angular displacement of knee was increased by about 9.3% in the landing compared to that without the backpack [12]. However, it was not clear whether the protection effects of knee brace on the lower-extremity joints were influenced by backpack in parachuting landing.

This study aimed to analyze the kinematic and kinetic parameters of hip, knee and ankle. The multi-joint protection of knee brace for those joints in parachuting landing with backpack would be evaluated. The two (without backpack vs. with backpack)×two (without knee brace vs. with knee brace) interaction significances were tested. It was hypothesized that multi-joint protection for hip, knee and ankle were provided by knee brace in parachuting landing both without and with backpack.

Section snippets

Participants

Seven healthy male participants (age: 22.3±3.0 years, height: 176.2±4.2 cm, weight: 67.6±6.2 kg) were recruited for the experiment. They had no history of musculoskeletal injury during recent one year and had regular exercises for more than eight hours per week. After informed consent, the participants were briefly provided with the details of the experimental purposes and procedures, and had trained the parachuting landing skill expertly before the testing. The right leg was the dominant one …

Results

The angular displacements, the angular velocities, the joint moments and the joint energy absorption of hip, knee and ankle on both sagittal plane and coronal plane, as well as the peak

vertical ground reaction force, all conformed to a normal distribution by using Kolmogorov-Smirnov methods.

The peak vertical ground reaction force was increased by the backpack from 14.74 ± 2.02 BW to 15.97 ± 1.64 BW (p=0.012), as shown in Table 1. No interaction significant difference in the peak vertical …

Discussion

The purpose of this study was to analyze the kinematic and kinetic parameters of hip, knee and ankle for exploring the multi-joint protection of the knee brace for those joints in the parachuting landing with the backpack. The hypothesis was that the knee brace could provide multi-joint protection for hip, knee and ankle in the parachuting landing both without and with backpack. It was found that the multi-joint protection of the knee brace was weakened by the backpack. …

Conclusion

Without the backpack, the knee brace provided the multi-joint protection on sagittal plane for hip, knee and ankle, and provided the protection on coronal plane only for knee. With the backpack, the knee brace still provide protection on sagittal plane and coronal plane for knee, but did not provide protection on sagittal plane and coronal plane for hip and ankle. The knee brace protected knee by restricting motion of knee and providing external joint moment for knee. …

Declaration of Competing Interest

None declared. …

Ethical approval

This study was approved by the Science and Ethics Committee of School of Biological Science and Medical Engineering in Beihang University, P. R. China (Approval ID: BM201900121). …

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References (29)

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Injury (1997)

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